**INDEX**

**Numerics**

802.1q VLAN specification, running MPLS/VPN, 357

**A**

address families
- routing context configuration, 209–211
- VPN-IPv4, configuring, 208

address space, overlapping, 164

address families, 207

advanced MPLS, troubleshooting, 115–118

advertisements
- AS-override, 196
- extended community attribute, 209
- PE routers, requirements for, 183

aggregates, 29

penultimate hop popping, 41

allocating labels
- across ATM LSR domains, 56–61
- distribution methods, 34–36
- independent control, 57
- VC merge, 58–61

AllowAS-in feature, deploying, 264–266

any-to-any connectivity
- Intranet topology, 184–185
- extranet topology, 153

applications
- hosting, 258
- MPLS, control protocols, 19–20

architecture
- cell-mode MPLS, control-plane connectivity, 51–53
- Edge-LSRs, 18
- MPLS/VPN, 13, 161–162
  - Extended Communities ORF-type capability, 219
  - FECs, 16
  - inter-PE router routing, 172–173
- Intranet topology, 184–185
- overlapping addresses, 190
- route distinguishers, 173

scalability, 173

SOO, 193, 196

VPNs
- route targets, 171–172
- sites, 169

area 0 (OSPF), PE-to-CE connectivity, 231, 238, 240–242

arguments, tag-switching advertise-tags command, 75

AS Override, 250–252

assigning
- interfaces to VRFs, 204
- labels. See bindings
- loopback addresses to PE routers, 348
- route distinguishers to VRFs, 411–412
- unique numbers to route distinguishers, 191–192

associating VRF with global routing table, 330–331, 334

ATM (Asynchronous Transfer Mode)
- backbone networks
  - migration to cell-mode MPLS, 108–110
  - migration to Frame-mode MPLS, 106–108
- service provider, convergence, 274
- cell-mode MPLS, 49, 69
- control-plane connectivity, 52–53
- limitations, 50
- frame-mode MPLS, 67–69
- heterogeneous MPLS-mode operation, 69
- Layer 3 lookup, 50
- LSRs, 50
  - convergence, 61–62
  - domains, 50
  - edge LSRs, 13–15, 50
  - IP connectivity, 51
  - labeled packet forwarding, 55–56
  - loopback interfaces, 53
- switches
  - control-plane implementation, 54
  - ordered control, 57
- VCs, 49
- attributes (BGP), 187
  - community, removing, 371
- extended community, 193
- advertising, 209
B  backbone
migration to Frame-mode MPLS, 97–99
MPLS/VPN
customer access, 225–226
deploying BGP, 344–355
OSPF route propagation, 235–238
route advertisements, 280–285	raceroute, 371–374
reachability, 342
service provider, convergence, 273–274
best path selection, reflected routes, 291
BGP (Border Gateway Protocol), 277
attributes, 187
community attribute, removing, 371
confederations
deploying, 300–305
multiple IGP environment, 306–309
single IGP environment, 305–306
deploying in MPLS/VPN backbone, 344–355
export policies, configuring, 195–196
extended community attribute, 193
format, 198
OSPF route propagation, 238
route target, 194–195
import policies, configuring, 195–196
internal sessions, 204
label bindings, 34
next hops, summarizing, 352–353
next-hop forwarding, 345–348
OPEN messages, Capabilities parameter, 205
PE-to-CE connectivity, 227–229
peering
group leader selection, 345
structure, 101–103
route reflectors, hierarchical structure, 288–289
Route Refresh, 215–217
scanner process, 278–279
selection process, 263
standard community extension, filtering on PE
routers, 294–297
unnecessary sessions, removing, 105
bindings, 12, 34
liberal retention mode, 273
Bottom of Stack bit, 27
BPX switches, LSC (Label Switch Controller), 54
business problem-based VPN classification, 132–134

C  calculating VCs per full-mesh networks, 148
Capabilities parameter (OPEN messages), 205
carrier’s carrier MPLS/VPNs, 378–380
external routes, 379
internal routes, 379
topologies, 381–392
case studies
migration
ATM backbone to cell-mode MPLS, 108–110
ATM backbone to Frame-mode MPLS, 106–107
backbone network to Frame-mode MPLS, 97–99
CEF requirements, 100
internal links to MPLS, 103–105
premigration infrastructure checks, 99–100
MPLS/VPN Intranet service, 184–185
SuperCom network VPNs, 162–164
VRF configuration, 186
CE (Customer Edge) devices, 131
PE-to-CE connectivity, provisioning, 311–312
tunneling to PE routers, 355
CEF (Cisco Express Forwarding) switching
assigning interfaces to VRFs, 204
interface-level, troubleshooting, 122–124
verifying, 429–430
cell-mode MPLS, 49
ATM LSRs, 50
loopback interfaces, 53
control-plane connectivity, 52–53
implementing in ATM switches, 54
IP connectivity, 51
loop prevention, 82–87
migration from ATM backbone networks, 108–110
over ATM, 69
central services topology, 152
VPNs, 258–261
central sites
extranet VPN connectivity, 256
IP tunneling, migration to VPN/MPLS, 415–418
CE-to-PE links
troubleshooting, 346
verifying routing exchange, 432–434
Cisco MPLS, 79
Cisco Secure Integrated Software, 315
Cisco VPN Solutions Centre, 358
classification of VPNs
business problem-based, 132–134
implementation models, 135–143
topologies, 144–157
class-of-service information, 26
clear ip bgp command, 217
clusters, route reflection between PE routers, 292
commands
clear ip bgp, 217
debug tdp transport, 31
ip ospf network point-to-point, 348
ip route, 201
ip vrf, 186
ip vrf forwarding, 204
maximum routes, 311
mpls ip, 31
mpls label-distribution, 31
neighbor advertisement-interval, 277
neighbor maximum-prefix, 311
network, 202
next-hop-self, 309, 344–346
ping, 426–428
propagate-ttl, 373
redistribute, 201, 235
redistribute bgp metric transparent, 203
route-maps, 201
router ospf, 233
route-target, 195
route-target export, 371
rr-group, 219
set extcommunity, 435
set extcommunity rt, 371
show atm vc, 54
show cef interface, 429
show ip bgp neighbor, 217, 283–284, 345
show ip ospf, 234
show ip route vrf, 434
show ip vrf detail, 435
show mpls forwarding-table, 116–117
show tag tdp neighbor, 33
show tag-switching forwarding-table, 220
show tag-switching tdp bindings, 36
show tag-switching tdp discovery, 121
show tag-switching tdp neighbor, 67, 75
tag tdp router-id, 33
tag-switching, MPLS equivalents, 461–462
tag-switching advertise-tags, 75–76
tag-switching ip, 31
tag-switching mtu, 80
common services VPNs, route distinguishers, 191
community attribute (BGP)
comparing standard and extended, 364–366
removing, 371
comparing
extended and standard BGP communities, 364–366
IP routing and IP forwarding tables, 166
VPN peer-to-peer models, 143
complexity of modern VPNs, 132
confederations
configuring, 302–305
deploying, 300–305
multiple IGP environment, 306–309
single IGP environment, 305–306
designing IGP, 302
configuring
AS Override, 251–252
ATM LSRs, loopback interfaces, 53
BGP, import/export policies, 195–196
confederations, 302–305
Internet access, 312–313
dynamic default routing, 328–334
performing additional global routing table lookup, 334
PE-to-CE connectivity, 320–328
separate service provider, 335
static default routing, 315–320
MP-iBGP, 207–209
MPLS/VPN, route reflectors, 219
PE routers
loopback addresses, 348
MP-iBGP, 420
summarization on loopback addresses, 349–354
PE-CE links, 200
route distinguishers, 191–192
route reflectors, ORF capability, 299–300
SOO extended community, 197–198
VRFs, 186
import/export policies, 195–196
connectivity, 414
cell-mode MPLS control plane, 51
central services topology (VPNs), requirements, 258
CE-to-PE links, troubleshooting, 346
control-plane
in Cisco IOS software, 52–53
end-to-end LSPs, 123
Internet access
configuring, 312–313
dynamic default routing, 328–334
firewalls, 313–315
performing additional global routing table lookup, 334
static default routing, 315–320
through separate service provider, 335
leased lines, 130
PE-to-CE, 200–203, 225
BGP-4, 227–229
convergence, 276–277
OSPF, 230–231, 238–242
OSPF without site area 0, 242–243
provisioning, 311–312
redistribution, 226
running separate BGP sessions, 320–321
tunneling, 355
VPN customer network topologies, 244–248
VRFs, separating, 232–235
PE-to-CE routing exchange
verifying, 432–434
pinging between CE routers, 426–428
route redistribution, verifying, 434–435
solutions
hierarchical VPNs, 392–394
inter-provider VPNs, 394–403
SuperCom network example, requirements, 167–169
VPNs, verifying, 428–429
conservative retention mode, 35
control modes, 73
control plane, 12
cell-mode MPLS, IP connectivity, 51
Cisco IOS software, 52–53
implementing in ATM switches, 54
troubleshooting, 118–121
control protocols
MPLS applications, 19–20
MPLSC, 27
convergence, 271
ATM LSR domains, 61–62
convergence, 271
ATM LSR domains, 61–62
between VPN sites, 275–280
frame-mode MPLS, 37–39
within service provider backbone, 273–274
Core LSRs, 25
core redundancy, WANs, 7
CPE (Customer Premises Equipment) devices, 131
VCs, frame-mode MPLS operation over Frame Relay, 65–67
customer links, network management, 358–367
export maps, 368–371
importing selected customer routes, 359–363
route filtering, 363–367
customer routes
advertising, requirements, 183
IGP, migrating to BGP, 339–344
next-hop forwarding, 345–348
D

data plane, 12
  cell-mode, loop prevention, 86–88
MPLS/VPN
  packet forwarding, 220–221
  troubleshooting, 122–124
datagrams, Maximum Initially Labeled IP Datagram Size, 79
debug tag tdp transport command, 31
dedicated router approach, peer-to-peer VPN model, 141–142
default behavior, ATM service provider backbone, 274
developing IP tunnels, migration case study, 410
delays, convergence over ATM LSR domains, 61–62
deploying
  AllowAS-in, 264–266
  BGP
    confederations, 300–305
    in MPLS/VPN backbone, 344–355
    confederations
      multiple IGP environment, 306–309
      single IGP environment, 305–306
    MPLS/VPN on LAN interfaces, 355–357
  Peer BGP
    on demand, 57, 121
draft-ietf-mpls-framework document, 11
dynamic default routing, configuring Internet access, 328–334

domains
  ATM LSRs
    convergence, 61–62
    label allocation and distribution, 56–61
    labeled packet forwarding, 55–56
  MPLS (frame-mode) convergence, 37–39
down-bit (summary LSAs), 241
downstream label distribution
  unsolicited, 34
  on demand, 57, 121
designing frame-mode MPLS domains, convergence, 37–39
detecting routing loops
  cell-mode MPLS, 82–88
  frame-mode MPLS, 81–82
devices
  CE, 131
  P devices, 131
  PE (Provider Edge), 131
  routers, LSRs, 13
dial-up lines, 129–130
differentiated services, IP packet forwarding, 9
distribution (labels)
  across ATM LSR domains, 56–61
  downstream on demand, 57
  on-demand, 35
  unsolicited, 34

e
Edge-LSRs, 13–14
  actions, 15
  architecture, 18
  Ingress, 25
  push action, 15–16
egress LSRs, 17
EIGRP (Enhanced Interior Gateway Routing Protocol), equal-cost load sharing, 6
encapsulation, 27–28
  across Ethernet links, 77
end-to-end convergence delay between VPN sites, 275
end-to-end LSP, verifying, 428–429
end-to-end MPLS path, monitoring, 123–124
equal-cost load sharing, EIGRP, 6
establishing
  LDP sessions, 31–34
  TDP sessions, 31–34
Ethernet
MPLS encapsulation, 77
PE routers, tunneling to CE routers, 355
evolution of VPNs, 129–131
examples
  migration
    ATM backbone to cell-mode MPLS, 108
    ATM backbone to Frame-mode MPLS, 106–108
    backbone network to Frame-mode MPLS, 97–99
    CEF requirements, 100
470 examples

F

Fast Ethernet, mapping VLANs to VPNs, 356–357
FECs (Forwarding Equivalence Classes), 16
  label binding, 74
  unicast routing, 34
filtering
  customer links, 363–367
  label mappings, 74–77
  ORF, 218
  VPN-IPv4 routes, 213–214
firewalls
  Cisco Secure Integrated software, 315
  Internet access, 313–315
flexibility of IP forwarding, 5
format of extended community attribute (BGP), 198
forwarding packets, 10
  label imposition, 16
  label swapping, 12
  VRF, 166
fragmenting packets, Path MTU discovery, 78
Frame Relay, frame-mode MPLS, 65–67
Frame-based LSRs, 50
Frame-mode MPLS
  control plane, loop detection, 82
  convergence, 37–39
  data plane, loop detection, 81
  label lookup, 28–29
  loop prevention, 81–82
  LSR capabilities, 29
  migrating
    from ATM backbone networks, 106–108
    from backbone network, 97–99
frames, giant, 124
full mesh topology
  route reflectors, 290
  VPNs, provisioning, 149
full mesh VPNs, 148–149

internal links to MPLS, 103–104
premigration infrastructure checks, 99–100
PE-to-CE connectivity, 226
SuperCom network
  connectivity requirements, 167–169
  loopback addresses, 24
experimental bits, 27
export maps, 368–371
export policies
  configuring, 195–196
  IP tunneling migration case study, 413
  route target, 194–195
exporting routes to specific targets, 367–371
Extended Communities ORF-type, 219
extended community attribute (BGP)
  advertising, 209
  comparing to standard community attribute, 364–366
  configuring, 197–198
  route target, 194–195
  SOO, 196–197
extended community attribute (BGP), 193
  format, 198
  OSPF route propagation, 238
extended ping command, 427–428
external controllers, LSC (Label Switch Controller), 54
external routes, 379
  propagation, 10
extranet topology, 150–152
  central services, 152–155
extranet VPNs
  central services, 152
  route distinguishers, 191
extranet/intranet integration, VPN architecture, 255–256
G

giant frames
  fragmentation, 78–80
  troubleshooting, 124
Gigabit Ethernet, restrictions on MPLS
  encapsulation, 77
global routing table
  associating with VRF, 330–331, 334
  performing additional lookup, 334
goal of MPLS, 11
GRE tunneling, migration to MPLS/VPN solution, 407–409, 413, 420
  configuring route reflectors, 418–420
  defining VPNs, 410
  routing policies, 410–414
  staging and execution, 414–418
  VPN site migration, 421
  VRF definitions, 411–412

H

heterogeneous MPLS-modes over ATM, 69
hierarchical structure
  route reflectors, 288–290
  PE routes, 290–291
  VPNs, 392–394
hop-by-hop destination-based unicast routing, 5
hub-and-spoke topology
  AllowAS-in feature, 264–266
  route distinguishers, 191
  SOO (Site of Origin) attribute), 265
  VPNs, 144–146, 261–263
  redundancy, 146
hybrid topology, overlay model, 150

I

iBGP, migrating to MPLS/VPN, 248–249
IETF (Internet Engineering Task Force)
  draft-eif-mpls-framework, 11
  web site, 11, 193

IGPs
  confederations
    multiple process configuration, 306–309
    single process configuration, 305–306
  customer routes, migrating to BGP, 339–344
implementation models (VPNS)
  overlay model, 135–137
  peer-to-peer model, 138–139
  dedicated router approach, 141–142
  shared router approach, 139–141
implementing
  BGP confederations, 300–305
  confederations
    multiple IGP environment, 306–309
    single IGP environment, 305–306
  control-plane in ATM switches, 54
  multiprotocol BGP in SuperCom network
  example, 174–177
implicit-null value, 41–42
import policies (BGP)
  configuring, 195–196
  IP tunneling migration case study, 413
  route target, 194–195
importing selected customer routes, 359, 362–363
in-band management virtual circuit, cell-mode MPLS, 51
independent control mode, 57, 73, 274
  frame-mode MPLS over Frame Relay, 65–67
  label assignment, 34
infrastructure of VPDNs, 156
Ingress Edge-LSRs, 25
  ingress PE-to-CE routing exchange, verifying, 439–440
interface-level CEF, monitoring, 122–123
interfaces
  assigning to VRFs, 204
  LC-ATM
    control-plane connectivity, 51
    downstream on demand, 57
    status, verifying, 53
    loopback, route summarization, 353
    partitioning, 355
  internal BGP sessions, 204
  internal links, migration to MPLS, 103–104
  internal routes, 379
Internet access
configuring, 312–313
dynamic default routing, 328–334
global routing table, additional lookup, 334
PE-to-CE connectivity, 320–328
firewalls, 313–315
global routing table, associating with VRF, 330–334
separate service provider, configuring, 335
static default routing, 315–320
inter-PE router routing, 172–173
inter-provider VPN solutions, 394–403
initiating packet labeling, 31
Intranet topology, MPLS/VPN, 184–185
route distinguishers, 191
intranet/extranet integration, VPN architecture, 255–256
IOS (Internetwork Operating System), control-plane connectivity, 52–53
IP
connectivity between ATM LSRs, 51
forwarding, 5
differentiated services, 9
external routing information
propagation, 10
tunneling, migration to MPLS/VPN solution, 407–409, 413, 420
configuring route reflectors, 418–420
defining VPNs, 410
routing policies, 412–414
staging and execution, 414–418
VPN site migration, 421
VRF definitions, 411–412
overlapping address space, 164
Path MTU
discovery, 78–80
MSS, 78
prefixes, propagation across MPLS VPN network, 430–431
routing
VRP, 166
summarization, 92–93
VPDN infrastructure, 156
ip ospf network point-to-point command, 348
ip route command, 201
ip vrf command, 186
ip vrf forwarding command, 204
ISPs, Managed Network service, 138

L
label imposition, Edge-LSRs, 15–16
label stack, 26, 30
Bottom of Stack bit, 27
penultimate hop popping, 40
implicit-null value, 41–42
two-level, 352–354
labels
allocation, VC merge, 58–61
allocation/distribution across ATM LSR domains, 56–61
binding, 34
conservative retention mode, 35
independent control, 57
liberal retention mode, 35
lookup, frame-mode MPLS, 28–29
mappings, filtering, 74–77
on-demand distribution, 35
packet forwarding, 10
across ATM LSR domains, 55–56
frame-based, 56
stack header, 26
swapping, 11
TTL propagation, 373–374
untagging, 29
label-to-prefix bindings, 34
LANs
encapsulation, 27–28
interfaces, MPLS/VPN deployment, 355–357
Layer 2 paths, selecting, 6–7
large-scale networks, route reflection, 289
Layer 2 paths, WANs selection, 6–7
Layer 3 lookup, ATM, 50
LC-ATM (Label Switching Controlled ATM)
interface, 50
control-plane connectivity, 51
downstream on demand, 57
status, verifying, 53
VCs, minimizing, 56
LDP (Label Distribution Protocol), 31
  sessions, establishing, 31–34
  troubleshooting, 118–121
  verifying operation, 118–120
leased lines, 129–130
LFIB (Label Forwarding Information Base) entries
  label lookup, frame-mode MPLS, 28–29
LIB (Label Information Base), 17
liberal retention mode, 35, 273
  Frame-mode convergence, 37–39
limitations of cell-mode MPLS, 50
limiting label mapping distribution, 73–77
links
  customer, managing, 358–371
  PE-CE
    configuring, 200
    convergence, 276–277
    RIP v2, 202–203
    running separate BGP sessions, 320–321
    static routing, 200–201
link-state routing protocols, OSPF, PE-to-CE
  connectivity, 230–231
load sharing, EIGRP equal-cost, 6
lookup, VPI/VCI, 49
loopback addresses
  configuring on PE routers, 348
  route summarization, 353
  SuperNet example, 24
  TDP/LDP identifiers, 75
loopback interfaces, ATM LSRs, 53
loops, preventing
  cell-mode MPLS, 82–87
  frame-mode MPLS, 81–82
  SOO, 196
LSAs (link-state advertisements), down-bits, 241
LSC (Label Switch Controller), 54
LSPs (Label Switched Paths), 17
  end-to-end connectivity, 123
LSRs (label switch routers), 13
  actions, 15
  ATM, 14–15, 50–51
  ATM-Edge-LSRs, actions, 15
  conservative retention mode, 35
  Core LSRs, 25
Edge, 14
  actions, 15
  architecture, 18
  Ingress, 25
  push action, 15–16
frame-based, 50
Frame-mode, capabilities, 29
label stack, 30
liberal retention mode, 35
loopback interfaces, 53
  pop action, 13
  push action, 13
Managed Network service, 138
managed network VPN topology, 157
managing customer links, 358–367
  export maps, 368–371
  importing selected customer routes, 359–363
  route filtering, 363–367
mapping VPNs to VLANs, 356–357
mappings (label), filtering, 74–77
Maximum Initially Labeled IP Datagram Size, 79
maximum routes command, 311
maximum session handling, route reflectors, 288
messages, Route Refresh, ORF entries, 218
migration strategies
  ATM backbone to cell-mode MPLS, 108
  ATM backbone to Frame-mode MPLS, 106–107
  backbone to Frame-mode MPLS, 97–99
  iBGP customers to MPLS/VPN, 248–249
  IGP customer routes to BGP, 339–344
  internal links to MPLS, 103–105
  IP tunneling to MPLS/VPN solution, 407–409, 413, 420
  configuring route reflectors, 418–420
  defining VPNs, 410
  routing policies, 410–414
  staging and execution, 414–418
  VPN site migration, 421
  VRF definitions, 411–412
migration strategies

partial migration, 104
premigration infrastructure checks, 99–100
minimizing VCs over LC-ATM interfaces, 56
monitoring
end-to-end MPLS path, 123–124
interface-level CEF, 122–123
MP_REACH_NLRI attribute, 205–206
MP_UNREACH_NLRI attribute, 205–206
MP-iBGP (Multiprotocol BGP), 187
configuring, 207–209
on PE routers, 420
PE routers, Route Refresh, 215–217
route distinguishers, 188
routing context, configuring, 209–211
static routes, redistribution, 201
SuperCom example configuration, 174–177
mpls ip command, 31
mpls label-distribution both command, 31
MPLS/VPN, 161. See also VPNs
architecture, 13
AS Override, 250–252
backbone
convergence between VPN sites, 275–280
customer access, 225–226
deploying BGP, 344–355
OSPF route propagation, 235–238
route advertisements, 280–285
traceroute, 371–374
carrier’s carrier, 378–392
control protocols, 19–20
customer routes, next-hop forwarding, 345–348
data plane, packet forwarding, 220–221
deploying on LAN interfaces, 355–357
Extended Communities ORF-type capability, 219
FECs, 16
inter-PE router routing, 172–173
Intranet topology, 184–185
goal of, 11
migration strategies
configuring route reflectors, 418–420
defining VPNs, 410
from iBGP, 248–249
from IP tunneling, 407–409, 413, 420
routing policies, 412–414
staging and execution, 414–418
VPN site migration, 421
VRF definitions, 411–412
MP-iBGP, 187
overlapping addresses, 190
PE routers
Automatic Route Filtering, 213–214
requirements for advertisements, 183
PE-to-CE link configuration
RIP v2, 202–203
static routing, 200–201
PE-to-CE connectivity
BGP-4, 227–229
OSPF, 230–231
route distinguishers, 173, 188
configuring, 191–192
route reflectors, configuring, 219
routes, importing, 195
SOO extended community, 193, 196
configuring, 197–198
VPN-IPv4 addresses, 207–208
VRFs
assigning interfaces, 204
configuring, 186
MPLSCP (MPLS Control Protocol), 27
MSS (maximum segment size), 78
MTU, Path MTU discovery, 78–80
multiprotocol extensions (BGP), 205

N
NBMA (non-broadcast multi-access), OSPF, PE-to-CE connectivity, 231
neighbor advertisement-interval command, 277
neighbor command, 208, 347
neighbor maximum-prefix command, 311
network command, 202
network layer packet forwarding, 5–6
network management, customer links, 358–367
export maps, 368–371
importing selected customer routes, 359, 362–363
route filtering, 363–367
networks (large-scale), route reflection, 289
next hops
  BGP, summarizing, 352–353
  penultimate hop popping, 40
  aggregates, 41
  implicit-null value, 41–42
  resetting at subconfederation boundary, 309
next-hop forwarding, 345–348
next-hop-self command, 309, 344–346
NLRI (Network Layer Reachability Information), 205
numbering route distinguishers, 191–192

O
on-demand distribution, 35
one-site-one-VRF model, 170
OPEN messages (BGP), Capabilities parameter, 205
optimization techniques (labels), VC merge, 58–61
optional, non-transitive attributes (BGP), 205–206
ordered control mode, 57, 73
ORF capability, 218
  configuring on route reflectors, 299–300
type definitions, 219
OSPF (Open Shortest Path First)
  PE-to-CE connectivity, 230–231
  VRFs, separating, 232–235
  without site area 0, 242–243
  route propagation over MPLS/VPN backbone, 235–238
  site area 0 support, PE-to-CE connectivity, 238–242
overlapping addresses, 164
MPLS/VPN, 190
overlapping VPs, 167–170
overlay VPN model, 135–137
  convergence, 275–280
  full-mesh, 148–149
  VCs, calculating, 148
  hub-and-spoke topology, 148
  hybrid topology, 130
  partial-mesh, 148
  PE-to-CE connectivity, OSPF, 230–231
oversized packets, 124

P
packets
  Ethernet encapsulation, 77
  forwarding
    encapsulation, 27–28
    external routing information propagation, 10
    label imposition, 16
    label swapping, 12
    MPLS/VPN data plane, 220–221
giant frames, troubleshooting, 124
Path MTU discovery, 78
partial mesh VPs, 148
partial migration strategy, 104
partitioning, 292
  interfaces, 355
Path MTU discovery, 78–80
PBR (policy-based routing)
  deploying, 10
  scalability, 10
PDBs (protocol descriptor blocks), 312
P devices, 131
PE (Provider Edge) devices, 131
  advertisements, requirements for, 183
  Automatic Route Filtering, 213–214
BGP
  route selection, memory requirements, 211
  sessions, activating, 207–208
loopback addresses
  configuring, 348
  summarization, 349–354
MP-iBGP, configuring, 420
ORF, 218
PDBs, 312
provisioning, 311–312
route filtering based on community value, 294
route reflection, 290–291
Route Refresh, 215, 217
routing policies, IP tunneling migration case study, 410
scaling PDBs, 312
standard community filtering, 296–297
tunneling to CE router, 355
VRFs, route distinguishers, numbering, 191–192
476 PE-ASBR routers

PE-ASBR routers, 396
PE-CE links, configuring, 200
   RIP v2, 202–203
   static routes, 200–201
peer group leaders, selecting, 345
peer-to-peer VPN model, 138–139
   comparing, 143
   dedicated router approach, 141–142
   shared router approach, 139–141
penultimate hop popping, 40–42
   aggregates, 41
   implicit-null value, 41–42
per-VPN routing protocols, 174
   redistribution, 176–177
PE-to-CE connectivity, 225
   BGP-4, 227–229
   convergence, 276–277
   iBGP customers, migrating to MPLS/VPN, 248–249
   ingress routing, verifying, 439–440
   MPLS/VPN backbone, customer access, 225–226
   OSPF, 230–231
      route propagation over MPLS/VPN backbone, 235–238
      site area 0 support, 238–242
      without site area 0, 242–243
   redistribution, 226
   running separate BGP sessions, 320–321
   VPN customer network topologies, 244–248
   VRFs, separating, 232–235
PHP (penultimate hop popping), 16, 179
   physical interfaces, partitioning, 355
   pinging between CE routers, 426–428
   P network, 131
   policies (BGP), import/export, VRF configuration, 195–196
   pop actions, 13
   pop tag, 29
   popping the label stack, penultimate hop popping, 40
   POPs, migrating route reflection to MPLS-based infrastructure, 98–99
   populating VRFs with customer routes, 225–226
prefixes
   propagation across MPLS VPN network, 430–431
   route summarization, 92–93
   unlabeled, 37
   prefix-to-label mappings, liberal retention mode, 35
   premigration infrastructure checks, 99–100
   preparatory steps, VPN packet forwarding, 177
   preventing
      labeled packet fragmentation, 79
      routing loops
         cell-mode MPLS, 82–87
         frame-mode MPLS, 81–82
      SOO, 196
   propagate-ttl command, 373
   propagation of MPLS VPN routes, verifying, 436–437
   protocols, ships-in-the-night, 54
   provisioning
      full-mesh VPNs, 149
      PE-to-CE connectivity, PE router configuration, 311–312
      virtual circuits, 8
   push action, 13
      Edge-LSRs, 15–16
   push tag, 29
   PVCs (permanent virtual circuits)
      ATM, frame-mode MPLS operation, 67–69
      shadow PVCs, 146
R

RD (route distinguisher), 177
reachability
   backbone networks, 342
   BGP, NLRI (Network Layer Reachability Information), 205
   recursive VPNs, 392–394
   redistribute bgp metric transparent command, 203
   redistribute command, 201, 235
   redistribution, 226
      into OSPF, 230
      per-VPN routing, 176–177
      verifying, 434–435
   VRF OSPF routes into MP-iBGP, 235–236
redundancy
hub-and-spoke VPN topology, 146
route reflectors, 289–290
reflected routes, 288
best path selection, 291
improving convergence time, 277
partitioning, 292
route filtering based on route target attribute, 297
removing
BGP community attribute, 371
unneeded BGP peering sessions, 105
requirements
BGP configuration in MPLS/VPN environment, 227
connectivity, SuperCom network example, 167–169
PE router advertisements, 183
VPNs
central services topology, 258
unique addresses, 165
restricting label mapping distribution, 73–77
restrictions
cell-mode MPLS, 50
Ethernet encapsulation, 77
retention modes (labels), 35
reusing AS numbers, 250–252
RIP v2, PE-to-CE link configuration, 202–203
route distinguishers, 173, 187–188
assigning to VRFs, 411–412
configuring, 191–192
VPN-Ipv4, 188
route filtering
automatic, 263
customer links, 363–367
route reflectors based on route target attribute, 297
route propagation across MPLS VPN network, 430–431
route redistribution, verifying, 434–435
route reflectors, 288, 292
hierarchical structure, 290
PE routes, 290–291
improving convergence time, 277
IP-iBGP, configuring for IP tunneling migration, 418–420
maximum session handling, 288
migration to MPLS-based infrastructure, 98–99
MPLS/VPN architecture, configuring, 219
ORF capability, 299–300
partitioning, 292
redundancy, 289–290
route target attribute-based filtering, 297
Route Refresh, 215–217. See also ORF
ORF entries, 218
route summarization, 92–93
loopback addresses, 353
route target attribute, 171–172, 194–195
extended community format, 199
route filtering on reflected routes, 297
route-maps command, 201
router ospf command, 233
router-on-a-stick, 288
routers
independent control, 57
LSRs, 13
actions, 15
ATM-Edge-LSRs, 15
ATM-LSRs, 14–15, 50, 55–56
Edge-LSRs, 14–15
Frame-based, 50
loopback interfaces, 53
pop action, 13
push action, 13
PE
MP-iBGP, configuring, 420
standard community filtering, 294–297
virtual routers, 165
routes
exporting to specific targets, 367–371
reflected, 288
VPN-Ipv4, selecting, 211–213
route-target command, 195
route-target export commands, 371
routing, per-VPN redistribution, 176–177
routing context, 175, 200
MP-iBGP configuration, 209–211
routing loops, 290
preventing
cell-mode MPLS, 82–87
frame-mode MPLS, 81–82
SOO, 196
VPNs, avoiding, 266
routing policies
IP tunneling migration case study, 412–414
PE routers, IP tunneling migration case study, 410
routing protocols
per-VPN, 174
VPN-aware, 200
routing tables
BGP, scanner process, 278–279
VRF, verifying route import function, 437–439
rr-group command, 219
sessions
BGP
activating between PE routers, 207–208
internal, 204
PE-to-CE connectivity, 320–321
LDP, establishing, 31–34
maximum handling capability of route reflectors, 288
MP-iBGP, scaling, 288
TDP, establishing, 31–34
set extcommunity command, 435
set extcommunity rt command, 371
shadow PVC, 146
shared router approach, peer-to-peer VPN model, 139–141
shim header, 27
ships-in-the-night, 54
show atm vc command, 54
show cef interface command, 429
show ip bgp neighbor command, 217, 283–284, 345
show ip ospf command, 234
show ip route vrf command, 434
show ip vrf detail command, 435
show mpls forwarding-table command, 116–117
show tag tdp neighbor command, 33
show tag-switching forwarding-table command, 220
show tag-switching tdp bindings command, 36
show tag-switching tdp discovery command, 121
show tag-switching tdp neighbor command, 67, 75
site area 0 (OSPF), 238–242
sites (web), IETF, 11, 193
software
Cisco IOS, control-plane connectivity, 52–53
Cisco Secure Integrated software, 315
Internet connectivity, 313–315
selection process
best path, reflected routes, 291
BGP, 263
peer group leaders, 345
customer routes to import, 359, 362–363
VPN-IPv4 routes, 211–213
service providers
application hosting, 258
backbone convergence, 273–274
services, central services topology, 258
scalability
IP forwarding, 5
MPLS/VPN architecture, 173
PBR, 10
PE routers, PDBs, 312
WANs, 7
scanner process, 278–279
security
central services, 153
firewalls
Cisco Secure Integrated software, 315
Internet connectivity, 313–315
specifying route targets for export, 367–371
stack header, 26
Bottom of Stack bit, 27
staging IP tunneling migration, 414–418
standard communities (BGP)
comparing to extended community attribute, 364–366
filtering on PE routers, 296–297
route filtering on PE routers, 294
starting MPLS packet labeling, 31
static default routing, 315–320
static routing, PE-to-CE link configuration, 200–201
stripping BGP community attribute, 371
stub sites, 200
sub-AS, label exchange, 309
subnet-to-label bindings, 34
summarization, 92–93
loopback addresses, 353
on PE loopback addresses, 349–354
SuperCom network example
loopback addresses, 24
multiprotocol BGP, implementing, 174–177
VPNs, case study, 162–164
swap tag, 29
switched WANs
ATM
cell-mode MPLS operation, 69
frame-mode MPLS operation, 67–69
Frame Relay, frame-mode MPLS operation, 65–67
switches
ATM
control-plane implementation, 54
Layer 3 lookup, 50
ordered control, 57
Ethernet, MPLS MTU, 80
VSI (Virtual Switch Interface), 54
syntax
route target command, 195
tag-switching advertise-tags command, 75
TFIB (Tag Forwarding Information Base), 18
TIB (Tag Information Base), 17
liberal retention mode, 35
topologies
BGP
confederations, deploying, 300–305
peering structure, 101–103
carrier’s carrier MPLS/VPN, 381–392
convergence
across ATM LSR domains, 61–62
between VPN sites, 275–280
within service provider backbone, 273–274
MPLS/VPN, Intranet, 184–185
PE-to-CE connectivity options, 226
route reflection
between PE routers, 290–291
hierarchical, 289–290
large-scale networks, 289
VPNs
central services, 258–261
central-services extranet, 152–155
customer networks, 244–248
extranet, 150–152
hub-and-spoke, 144–146, 261–263
managed network, 157
VPDN, 155
traceroute, 88–92
between VPN sites, 371–374
traffic, forwarding, 10
TransitNet migration examples, 97
troubleshooting
CE-to-PE links, 346
control plane, 118–121
LDP, verifying operation, 118–120
MPLS, 115
checks, 116–118
data plane, 122–124
TDP, verifying operation, 118–120
traceroute utility, 88–92
TTL (Time-To-Live) field, 26
propagation, 373–374
tuning BGP scanner process, 279
tunneling PE-to-CE routers, 355
two-level label stacks, 352–354
unicast routing, FECs, 34
unique addresses, VPNs, 165
unique numbers, assigning to route distinguishers, 191–192
unlabeled prefixes, 37
unsolicited downstream label distribution, 34
frame-mode MPLS over Frame Relay, 65–67
untag, 29
cpdate-source parameter (neighbor command), 347
utilities, traceroute, 88–92
between VPN sites, 371–374

VC lookup operation, 49
VC merge, 58–61
VCI (virtual circuit identifier), 49
VCs (Virtual Circuits), 131
frame-mode MPLS over Frame Relay, 65–67
in-band management, 51
minimizing on LC-ATM interfaces, 56
provisioning, 8
PVCs, shadow PVCs, 146
verifying
CE-to-PE routing exchange, 432–434
imported customer routes, 366–367
ingress PE-to-CE routing exchange, 439–440
LC-ATM interface status, 53
LDP label exchange, 121
LDP operation, 118–120
MPLS VPN operation, 426
CEF switching, 429–430
connectivity, 426–429
propagation of MPLS VPN routes, 436–437
proper MPLS setup, 116–118
route import functionality, 437–439
route redistribution, 434–435
TDP operation, 118–120
label exchange, 121
virtual routers, 165
VLANs
802.1q, running MPLS/VPN, 357
mapping to VPNs, 356–357
VPDN (Vrtual Private Dialup Network) topology, 155
VPI (virtual path identifier), 49
VPN-aware routing protocols, 200
VPN-IPv4, 188
addresses, MP-iBGP configuration, 207–208
Automatic Route Filtering, 213–214
route exchange, configuring, 208
route selection, 211–213
VPNs
business problem-based classification, 132–134
central-services extranet topology, 152–155
Cisco VPN Solutions Center, 358
complexity of, 132
customer network topologies, 244–248
defining, IP tunneling migration case study, 410
evolution of, 129–131
extranet topology, 150–152
extranet/intranet integration, 255–256
full-mesh topology provisioning, 149
hierarchical, 392–394
hub-and-spoke topology, 144–146, 261–263
AllowAS-in feature, 264–266
redundancy, 146
inter-provider, 394–403
label allocation, 178
managed network topology, 157
mapping to VLANs, 356–357
overlapping, 167–170
overlay model, 135–137
full-mesh, 148–149
hybrid topology, 150
OSPF, PE-to-CE connectivity, 230–231
partial-mesh, 148
packet forwarding, 177–179
peer-to-peer models, 138–139
comparing, 143
dedicated router approach, 141–142
shared router approach, 139–141
per-VPN routing, redistribution, 176–177
PE-to-CE subnets, 426–428
requirements for unique addresses, 165
route distinguishers, 173
route targets, 171–172
routes, importing, 195
routing loops, avoiding, 266
sites, 169
SuperCom network example, 162–164
topologies, central services, 258–261
VPDN topology, 155
VRF (VPN routing and forwarding) table, 165–166, 175
associating with global routing table, 330–331, 334
configuring, 186
import/export policies, 195–196
customer routes, importing, 359–363
defining for IP tunneling migration, 411–412
interfaces, assigning, 204
one-site-one-VRF model, 170
populating with customer routes, 225–226
route distinguishers
configuring, 191–192
numbering, 191–192
route distinguishers, assigning, 411–412
route filtering, 363–367
separating on PE-to-CE links, 232–235
VSI (Virtual Switch Interface), 54

WANs
ATM
cell-mode MPLS operation, 69
heterogeneous MPLS-mode operation, 69
MPLS operation, 67–69
core redundancy, 7
Frame Relay, MPLS operation, 65–67
Layer 2 paths, selecting, 6–7
virtual circuits, provisioning, 8
web sites, IETF, 11, 193